POWER SUPPLIES FOR MAGNETS AT NAL

Richard Wilson
Harvard University

July 11, 1968

This is propaganda for a point of view first expressed by the writer in 1959; it did not find acceptance at CEA, and the writer does not know why. So, we start again in the hope it is of use at NAL. We want to make cheap, efficient and simple supplies and not to make them more complex than we need.

Grounding

I believe that all magnets and associated supplies should be floating to ground and not tied to ground. At first sight this seems unsafe. I wish to show that it is safer than the usual procedure. In Fig. 1, consider two safety problems.

1. Personnel protection from voltage. Both procedures are the same in the absence of a large ground current. In the recommended procedure a large ground current switches off the supply within 1/2 second anyway.

2. A ground short in the magnet or magnet circuit. These are rarer nowadays than they used to be. However, when they occur in a 1 megajoule magnet they are scary. In the usual system a large fraction of the 1 megajoule has to dissipate in the short. Copper melts and flies across the room. In my recommended system a large ground current

flows; the relay trips and the power supply switches off. Nothing more violent happens.

Cooling

CEA bought power supplies from New York State. The transformer, saturable reactors and rectifiers are air cooled. The company resists water cooling because, they say, customers have dirty water, etc. But we know how to deal with cooling water for our magnets (and in fact dissipate ten times the heat in the magnets as in the supplies). We should resist that argument and water cool with its attendant size and cost advantages.

Fusing etc.

The CEA supplies have fuses etc. to protect the rectifiers. Fuses cost about \$40 each, the rectifiers \$6. This is clearly stupid. We should parallel rectifiers to derate by a large factor since they are cheap. Then there is no need for current-equalizing inductors either.

Weight and Location of Parts

If a magnet is designed for fair economy of power, the weight and size of a water-cooled transformer is 1/10 the weight of its magnet. It is negligible, therefore, to put it close to the magnet. For a large magnet the system becomes 6 ϕ full wave not 3 ϕ full wave with a $Y\Delta$ transformer.

Ripple

The ac voltage ripple is about 5% of full output voltage at high output, or 100% of full output voltage at low output. It is 360 Hz (or 720 for 6 ϕ full wave). The current ripple is complicated by fringe field and eddy current effects, but the field ripple in $\int Bdl$ should be the same quantity divided by

$$2\pi \times 360 \text{ (or 720 for } 6\ \phi) \times T \approx 2000 \text{ for } T = 1,$$

where T = energy stored/power supplied is the time constant of the magnet. We shall probably use the same cooling water (and water from circuit!). The rectifiers are trivial in size when water cooled (no cooling fins). I suggest therefore the following package for small magnets. See Fig. 2.

The control circuit contains: current and voltage feedback elements and is typically collected in one place. The cutout for ground current, over i, over r, are located here also, with leads to wherever the 3500 V cutout is located.

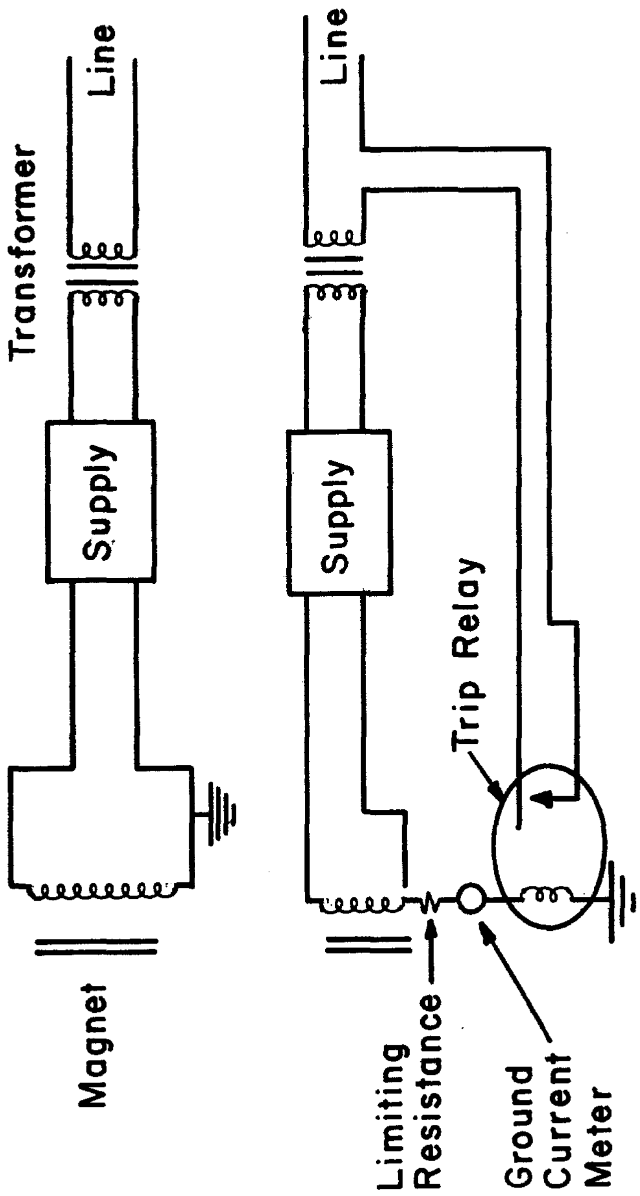

Fig. 1. Above--usual procedure, and below, recommended procedure for grounding magnet power supplies.

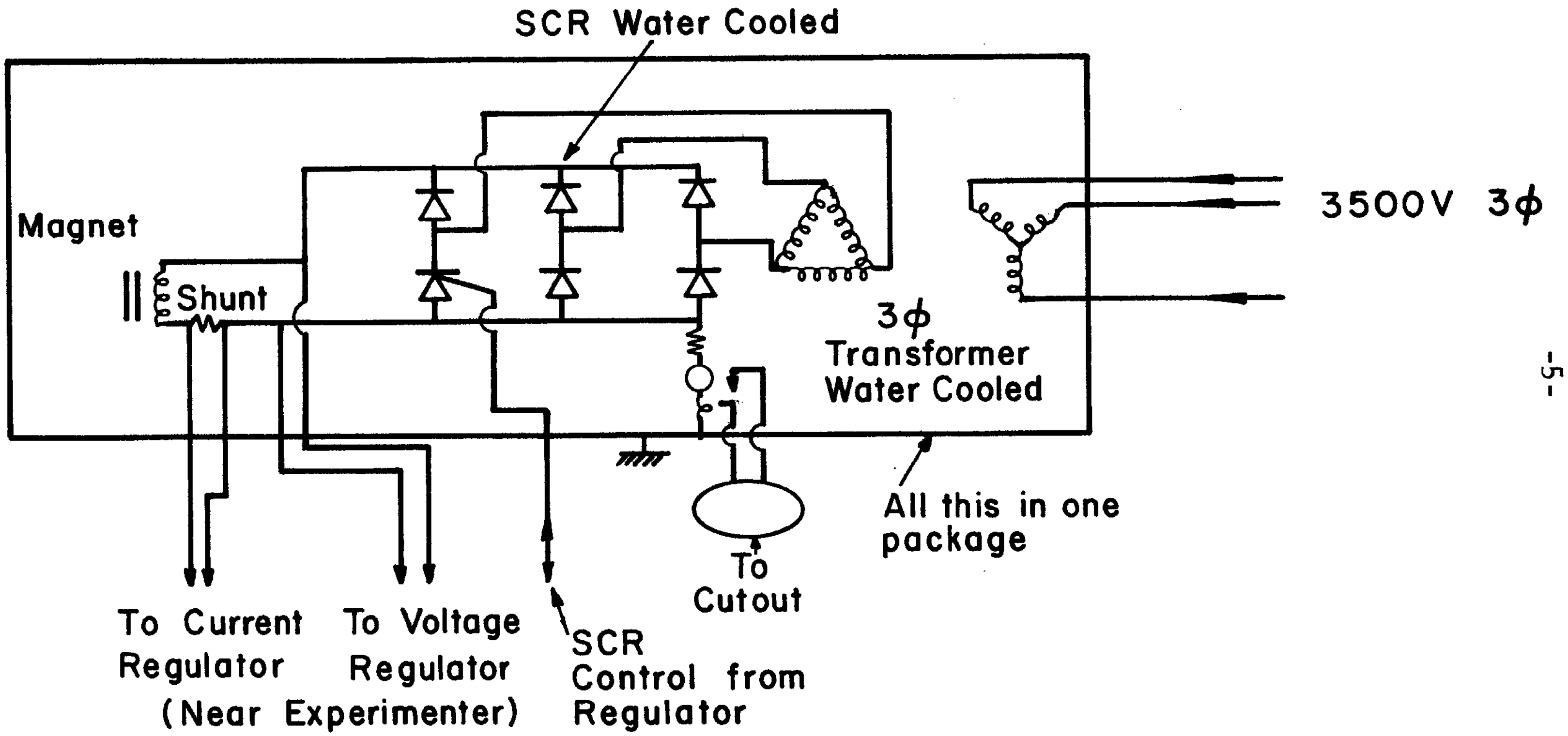

Fig. 2. Suggested packaging arrangement for experimental magnet power supplies.